Federal Aviation Administration Integrated Noise Model

U. S. DEPARTMENT OF TRANSPORTATION

Federal Aviation Administration
Office of Environmental Quality
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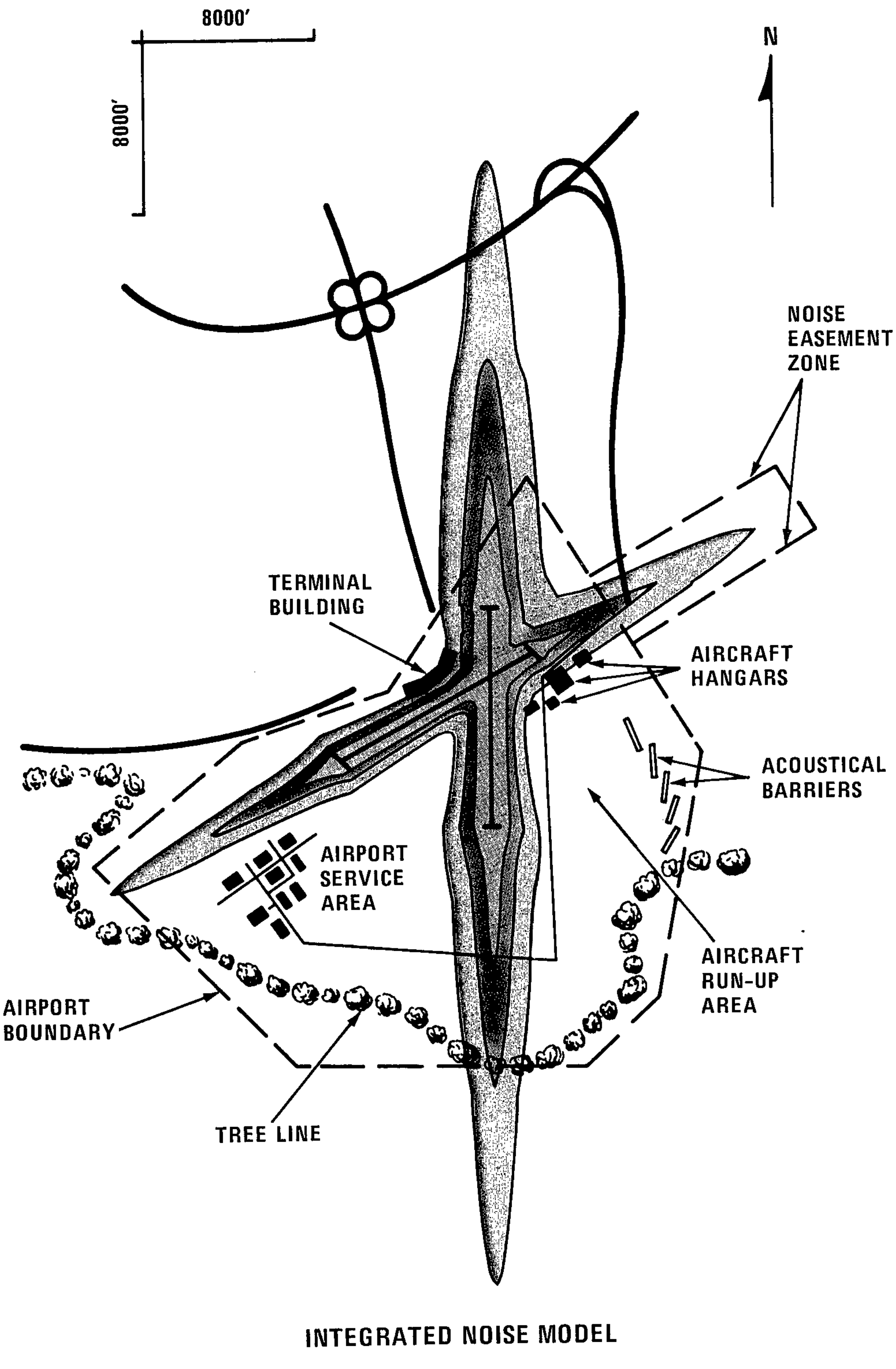

INTEGRATED NOISE MODEL

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INTRODUCTION

The Department of Transportation (DOT)/Federal Aviation Administration (FAA) has developed a valuable noise-simulation computer-based tool for describing and defining the impact of aircraft noise around an airport. This tool, known as the Integrated Noise Model (INM), became available to the public in 1977, and is useful in assessing actual or predicted airport noise impacts. The INM takes into account all pertinent impact parameters including types and numbers of aircraft operating at the airport, flight tracks, operating procedures, and time of day of aircraft operations.

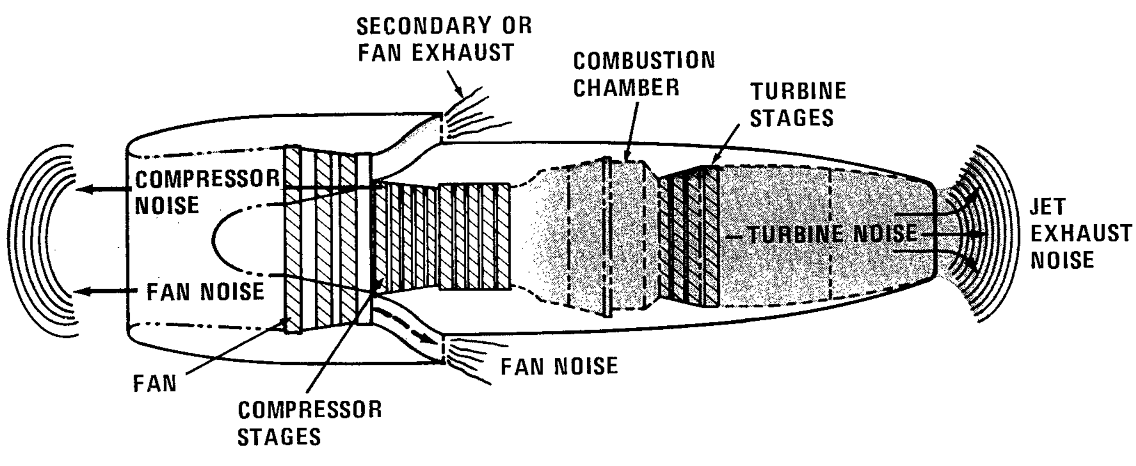
This brochure is intended to familiarize the reader with the capabilities and characteristics of the INM. It will also provide a better understanding of aircraft noise, the need for the INM, and its potential applications.

The Cause of Jet Airplane Noise - The Engine

The vast majority of aircraft noise disturbances near airports are due to the operation of commercial jet air carrier airplanes. Although the movement of an aircraft flying at subsonic speed generates some noise due to turbulence, the primary source of jet aircraft noise is the engines.

The two principal sources of noise from turbofan engines are the jet exhaust and the fan/compressor, as shown in Figure 1. Jet exhaust noise-the roar of the primary jet exhaust-comes from turbulent mixing of high-velocity exhaust gases with the ambient air. The jet exhaust generates sound energy over a wide band of frequencies. During a fly-over, the exhaust noise will increase after the aircraft has passed overhead, and reach a maximum when the listener is located at approximately a 45-degree angle to the jet exhaust axis. Turbo-machinery noises of the jet engine are generated within the fan, compressor, and turbine rotating elements. The sounds from the turbo-machinery encompass many frequencies and may contain high frequency tones that screech and are particularly annoying.

FIG. 1



ENGINE NOISE SOURCES

The perceived noise from any source decreases as the distance is increased between that source and people. Aviation noise is a problem near airports, where aircraft are flying near the ground as they depart or arrive.

Characteristics of the Takeoff and Landing Operations

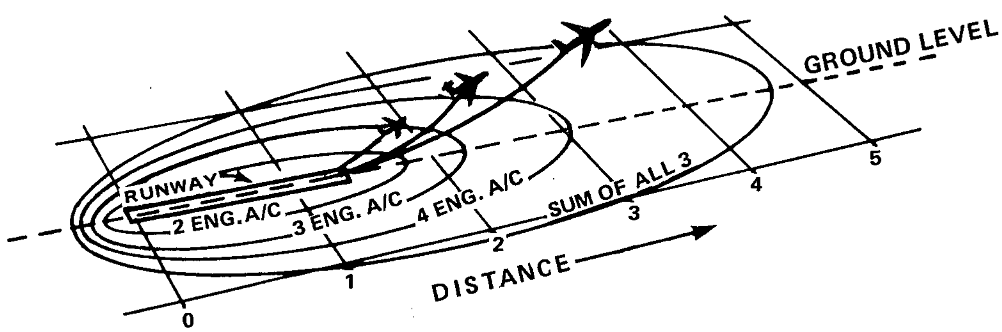
Takeoff Noise

Aircraft use their highest power during takeoff. While the level of this power varies with the type and size of the airplane, all are at their noisiest during takeoff. Typical patterns of noise reaching the ground for various types of airplanes during takeoff are illustrated in Figure 2.

FIG. 2

NOISE PATTERNS

TAKEOFF



Since the noise heard depends on both the intensity of sound at the source and the distance between the source and the receiver, it is important for the airplane to reach optimum altitude before overflying residential areas. At certain airports where residential communities are close to the runway, flexibility in the takeoff procedure allows power cutbacks (see Figure 3), which can be initiated after the airplane has reached a safe altitude in order to reduce the source noise (Figure 4).

FIG. 3

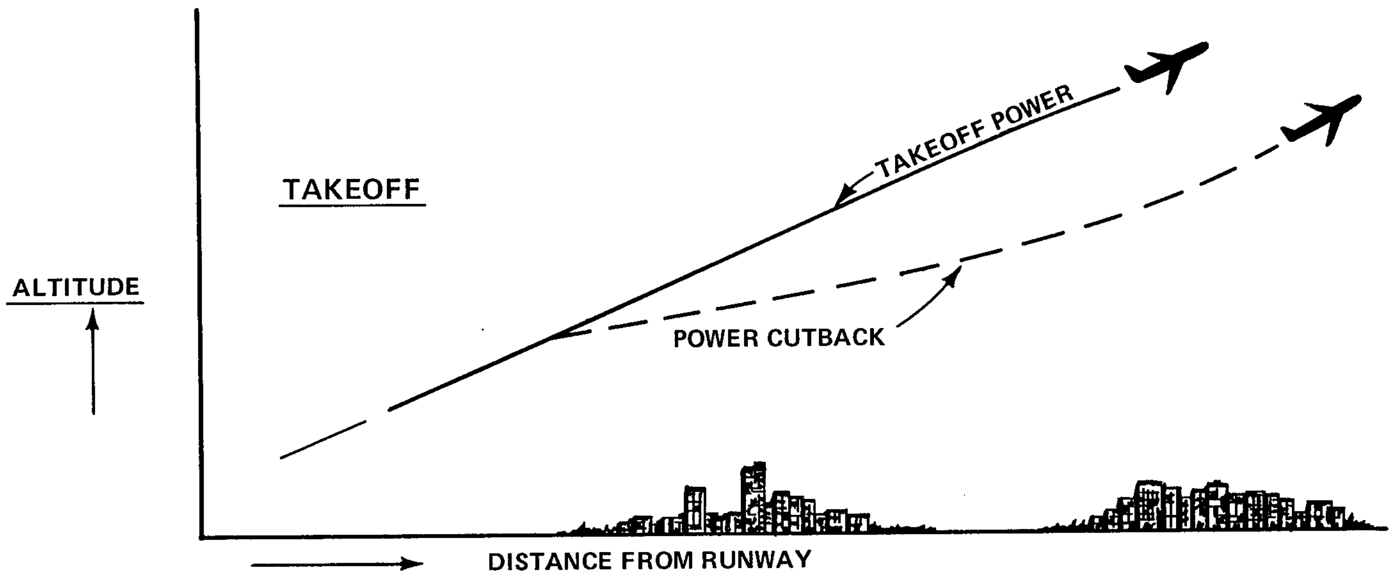
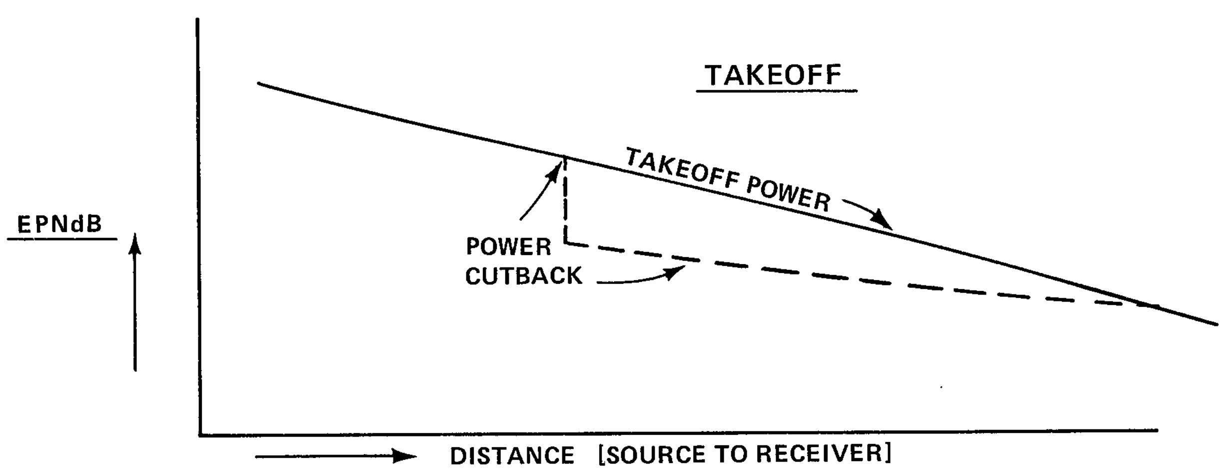

TAKEOFF
TAKEOFF POWER
ALTITUDE
POWER CUTBACK
DISTANCE FROM RUNWAY

FIG. 4


TAKEOFF
TAKEOFF POWER
EPNdB
POWER
CUTBACK
DISTANCE [SOURCE TO RECEIVER]

The power cutback procedure, however, reduces the airplane's rate of climb. This results in the airplane being at a lower altitude over areas farther away from the runway (see Figure 3) thus exposing those areas to more noise than if the original climb-power had been sustained. The best solution depends on the location of noise-sensitive areas, and will differ from site to site.

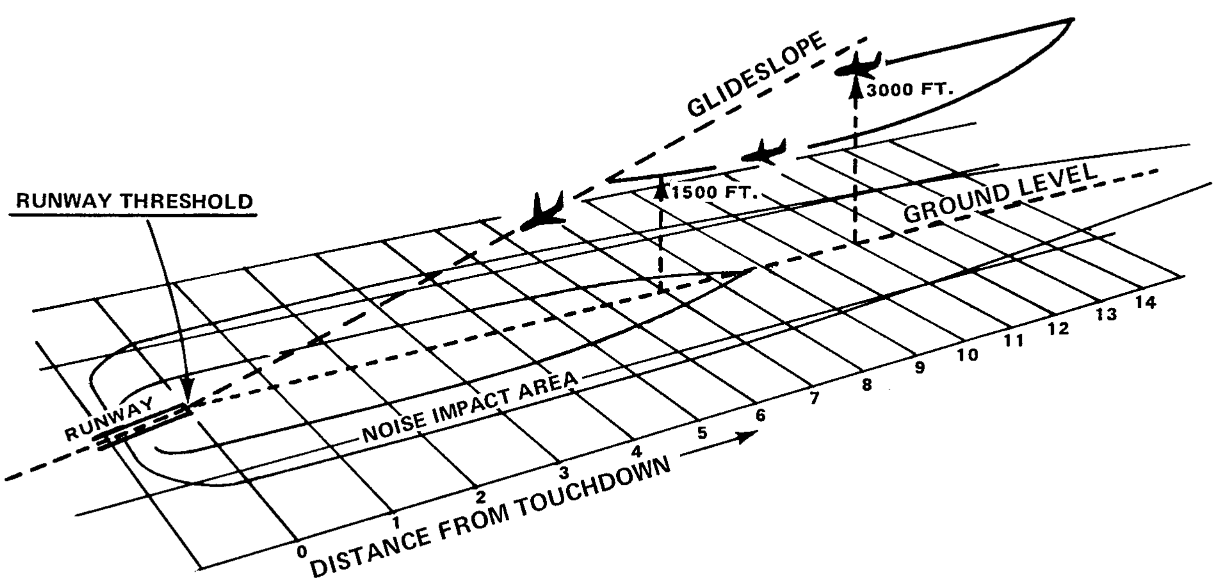
Additional flexibility exists for takeoffs in that flight tracks may be prescribed which permit airplanes to avoid flying over noise-sensitive areas after safe altitudes have been attained.

Landing Noise

Airplane engines produce less noise during the approach-to-landing operation because lower power is required. However, the noise produced from the fan-compressor in some airplanes may be more annoying because of its screech or whine characteristics. Additionally, less flexibility is afforded in this operation compared to the takeoff procedure since a gradual descent for a landing usually begins 5 to 10 miles away from the airport, normally following a 3 degree "glideslope." This results in a constantly increasing noise level on the ground, as the aircraft comes closer to the airport. The noise diagram for this operation is depicted in Figure 5, which shows a 1500 ft. glide slope intercept as well as a 3000 ft. intercept. This higher flight track reduces the noise level on the ground.

FIG. 5

APPROACH-TO-LANDING



A Simulation Model to Define Airport Noise Impacts

Noise impact of any one airplane takeoff and/or landing depends on many factors. The noise generated by the specific airplane, the power being used, the airplane's performance, and the airplane's flight path in the air are all pertinent. Where more than one airplane is in operation, additional parameters must be considered to define noise impact. Such parameters are the total airport mix of airplane types and the varying flight tracks; the operational procedures; the total number of takeoff and landings by airplane type; and, the time of day of each takeoff and landing. Only after consideration of all pertinent factors can a full understanding be achieved of the noise impact of a given airport's operation.

Airport noise impact can be expressed in a number of "noise metrics" depending on the preference of the user, the ultimate objective of the impact assessment, or both. The INM, developed to satisfy user requirements, provides these metrics.

Noise metrics available from the model are "cumulative metrics", such as the Noise Exposure Forecast (NEF), Day-Night Average Sound Level (Ldn), Equivalent Sound Level (Leq), Community Noise Equivalent Level (CNEL), and "exposure metrics" in Time Above (TA) a number of user specified A-weighted sound levels in decibels, e.g., dBA (TA_{85}, TA_{95}, etc.). See Appendix A for further discussion of these metrics.

Noise contours can be computed and printed at selected map scales. The user may plot contours of any of the four cumulative energy metrics or contours of equal exposure in minutes for TA specified A-weighted sound levels. The user will normally choose the single metric of greatest interest for contour plotting, but more than one metric may be used.

The model automatically provides numerical listings of the calculated noise values at all intersecting points on a grid, which encompasses the airport and surrounding neighborhoods. This printed output includes computations of any or all of the four metrics based on accumulated acoustical energy, and Time Above A-weighted sound levels for six selected noise thresholds, from 65 decibels to 115 decibels. The time of exposure calculations are further broken down into three daily periods: 1) a 24-hour day, 2) evening hours (7 p.m. to 10 p.m.) and 3) night hours (10 p.m. to 7 a.m.).

The model's data base contains common flight profiles and noise characteristics for numerous aircraft types. Changes to this built-in aircraft noise and performance data base can be accomplished through user option commands.

The noise file for each aircraft consists of noise-vs-slant-range (distance between airplane and the receiver) curves for several thrust settings. The user options are designed so that changes can be made to data from these files, if necessary. The scale of the contour map can be specified by the user as well as the spacing of the grid points for which numerical answers are provided.

INM Outputs

The program output consists of a printout of the input data, plotted noise contours, and computed noise levels at the grid points. With the input data listed prior to calculations, the user may check for possible errors which occurred while assembling or entering the data.

The contours for a sample case are shown in the figure on page 8. Included in this example are equal noise coordinates for any of four cumulative energy metrics and Time Above 65, 75, 85, 95, 105 and 115 dBA. The user may specify the contour plot scale so it matches the scale of a desired map. The runways are drawn on the contour to provide visual orientation and reference when the contours are used as overlays on maps of the same scale.

Calculations of grid points specified by the user are printed in tabular form as shown on page 9. A lettered code relates the tabular data to grid intersections on the contour map. This facilitates the location of user specified grid points on the contour plot. For example, the coordinate (1,D) as seen on the grid-tabulated form shows the following information about that location for a 24-hour period:

(1) Time Above 75 dBA = 30.3 min/24 hrs; 4.4 min/evening; 3.6 min/night
(2) Time Above 85 dBA = 9.8 min/24 hrs; 1.3 min/evening; 1.3 min/night
(3) Time Above 95 dBA = 0.9 min/24 hrs; .2 min/evening; .1 min/night
(4) Leq = 70.8;
(5) Ldn = 73.9;
(6) NEF = 38.8; and,
(7) CNEL = 74.5.

This, plus additional information is shown in tabular form on page 9.

This location can be referenced on the contour map by locating the coordinate (1,D) and should agree with any contour point if computed for that location. The grid analysis is particularly suited to determine the noise impact of specific locations without computing unnecessary information.

How the INM May Be Used

Various individuals or organizations may have use for the INM including:

(1) airport proprietors - to gain a better understanding of the noise impacts of the operation of their airport or in the preparation of an environmental impact statement;

(2) airport consultant - to better assist their clients in planning for future expansion or revision of current airport operations;

(3) state or local authorities - to identify sensitive noise areas which can then be appropriately zoned for compatible land use; or,

(4) the FAA - as an aid to assess the impacts of proposed revised terminal area operating procedures.

In addition to the above, a land planner or developer would find the INM a useful tool to determine the specification he should use for noise transmission by structures planned for construction near an airport. Additionally, private citizens may avail themselves of the use of the INM.

Several specific uses of the INM suggest themselves from the preceding illustration:

- Development by local governments of land use controls or limits on utility hookups to bring about noise compatibility.

- Comparison of different aircraft types and fleet mixes which could use the airport, including alternative schedules for their use.

- Comparison of aircraft operational procedures and flight tracks.

- Use in Noise Control and Land Use Compatibility Plans.

- Use in assessing noise impacts when necessary for environmental impact statements.

- Identification of future noise easement or airport land acquisitions.

- Determination of optimal locations for on-airport acoustical barriers.

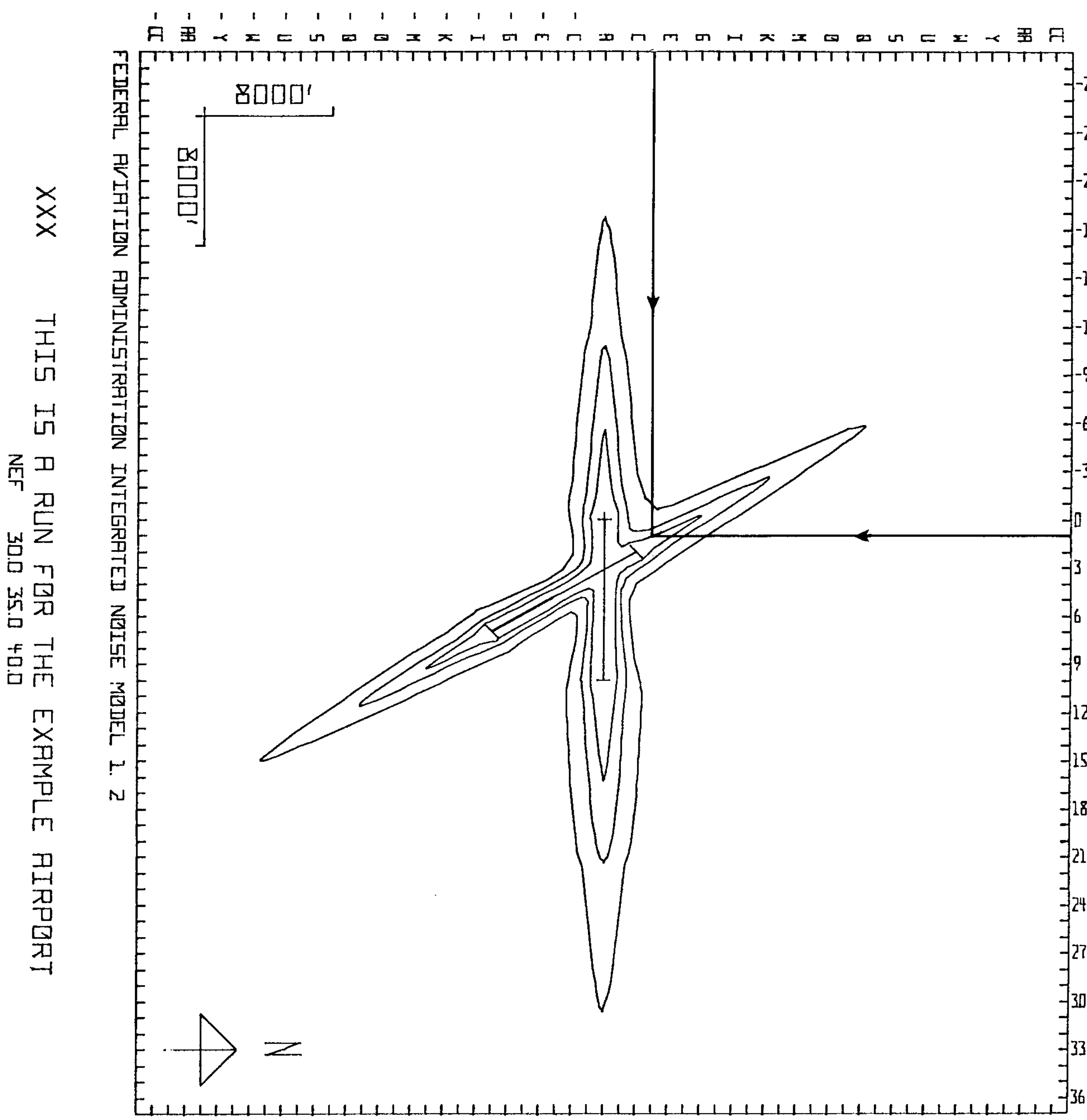
- Development of dedicated restricted areas of on-airport noise - causing operations, e.g., engine runups.

INM Enhancements

Comprehensive as the capabilities of the INM are, improvements or new uses involving increased flexibility are important in improving the state-of-the-art. Based on day-to-day applications of the INM, work will continue to expand its scope, improve its functional efficiency, and provide new parameters to further serve the user's needs.

Availability

The Integrated Noise Model is currently available for use from time-sharing vendors. The FAA encourages Federal, state, and local officials and other interested parties to use the INM for aviation noise assessments. Additionally, the program for the model is available from the FAA on a loan basis. For information concerning use of the model, please refer to the "FAA Integrated Noise Model Version I: Basic User's Guide" (Report FAA-AEQ-78-01, January 1978). Comments, suggestions or other inquiries concerning the INM may be sent to the Federal Aviation Administration, Office of Environmental Quality, AEQ-110, 800 Independence Avenue, SW., Washington, D.C. 20591.


XXX THIS IS A RUN FOR THE EXAMPLE AIRPORT
NEF 30.0 35.0 40.0
FEDERAL AVIATION ADMINISTRATION INTEGRATED NOISE MODEL 1.2
8000'
8000'
N

12/27/77.

FEDERAL AVIATION ADMINISTRATION INTEGRATED NOISE MODEL 1. 2
THIS IS A TEST OF MULTIPLE POINT GRID OUTPUT

12/28/77.

INTER-SECTION	OFF SET	PERIOD	TIME IN MINUTES ABOVE INDICATED DHA LEVEL 65	75	85	95	105	115	LEQ	LDN	NEF	CNEL
0. B		24 HOUR	65.3	31.2	13.4	4.4	0.0	0.0	71.9	75.1	39.1	75.6
		EVENING	9.4	4.5	2.0	.7	0.0	0.0				
		NIGHT	8.3	3.8	1.5	.5	0.0	0.0				
1. B		24 HOUR	67.4	35.3	14.1	4.0	0.0	0.0	71.2	74.4	38.4	74.9
		EVENING	9.5	5.1	2.2	.6	0.0	0.0				
		NIGHT	8.5	4.3	1.5	.4	0.0	0.0				
0. C		24 HOUR	67.5	33.3	13.1	0.0	0.0	0.0	66.4	69.7	33.1	70.1
		EVENING	9.8	4.9	2.0	0.0	0.0	0.0				
		NIGHT	8.5	4.1	1.5	0.0	0.0	0.0				
1. C		24 HOUR	70.7	34.2	13.6	1.3	0.0	0.0	69.3	72.4	36.4	73.0
		EVENING	10.0	5.0	2.1	.2	0.0	0.0				
		NIGHT	8.9	4.1	1.6	.1	0.0	0.0				
0. D		24 HOUR	68.2	31.7	10.3	.1	0.0	0.0	65.1	68.4	32.0	68.8
		EVENING	9.8	4.6	1.3	.0	0.0	0.0				
		NIGHT	8.5	3.9	1.3	.0	0.0	0.0				
1. D		24 HOUR	68.8	30.3	9.8	.9	.0	0.0	70.8	73.9	38.8	74.5
		EVENING	9.9	4.4	1.3	.2	.0	0.0				
		NIGHT	8.7	3.6	1.3	.1	0.0	0.0				
0. E		24 HOUR	65.8	29.9	5.0	.4	0.0	0.0	66.6	69.8	34.0	70.3
		EVENING	9.4	4.4	.7	.1	0.0	0.0				
		NIGHT	8.3	3.6	.7	.0	0.0	0.0				
1. E		24 HOUR	66.7	29.0	4.8	1.2	.1	0.0	73.5	76.6	42.8	77.3
		EVENING	9.5	4.2	.7	.2	.0	0.0				
		NIGHT	8.4	3.5	.6	.1	.0	0.0				
0. F		24 HOUR	59.5	27.5	4.0	1.1	.1	0.0	69.6	72.7	38.3	73.4
		EVENING	8.5	4.1	.6	.2	.0	0.0				
		NIGHT	7.4	3.4	.5	.1	0.0	0.0				
1. F		24 HOUR	62.7	28.8	4.0	.6	.0	0.0	67.4	70.6	35.3	71.2
		EVENING	8.9	4.2	.6	.1	0.0	0.0				
		NIGHT	7.8	3.6	.5	.1	0.0	0.0				

X-START	Y-START	X-STEP	Y-STEP	NX	NY	OPTIONS
0.00	1000.00	1000.	1000.	2	5	*****

APPENDIX A

This appendix presents an overview of the noise metrics which are contained in the INM. A brief discussion of each noise metric is provided. The discussion includes definitions, additional descriptive language concerning each metric, a brief treatment of the use of different INM outputs, and correlations between the metrics.

DEFINITIONS

The noise metrics available in the INM may be defined as follows:

Leq (Equivalent A-weighted Sound Level) - unit is dB

Leq is the average (i.e., the average on an energy basis) noise level (usually A-weighted sound level) integrated over some specified amount of time. The A-weighted sound level (LA) is a sound pressure level which has been fitted or weighted to approximate the human ear's perception of sound. Leq provides a single number measure of time-varying noise for a predetermined time period.

Ldn (Average Day-Night A-weighted Level) - unit is dB

Ldn is the average (i.e., on an energy basis) A-weighted sound level integrated over a 24-hour period, with an arbitrary weighting applied for the noise levels occurring in nighttime periods.

Its purpose is to provide a single number measure of the impact of time-varying noise over a 24-hour period. It was developed for noise exposure surveillance and as an aid in land use planning.

NEF (Noise Exposure Forecast) - scale is in dB

NEF is the cumulative impact of aircraft noise over a 24-hour period (weighted for the time of day) of Effective Perceived Noise Level (EPNL). NEF is used to determine the relative noise impact of aircraft noise.

CNEL (Community Noise Equivalent Level) - unit is dB

CNEL is the average (i.e., average on an energy basis) A-weighted sound level for a 24-hour period with different weighting factors for the noise levels occurring during the day, evening, and nighttime periods. The CNEL is used in the assessment of noise impact areas around airports.

TA (Time Above a Threshold of A-Weighted Sound Level) - unit in minutes

TA is the total time that a preselected, A-weighted sound level is exceeded due to aircraft operations during a specified period of time.

Description of Metrics

The noise metrics available in the INM deal basically with two characteristics of noise: the noise intensity and the number of occurrences of the noise events. Metrics in the INM which have the ability to deal with specific divisions of time of day are NEF, Ldn, CNEL and TA. The metrics in the INM can account for the acoustical effects of nonstandard conditions of field elevation and temperature; however, they do not account for seasonal effects. Based on these considerations, the metrics can be grouped under three headings:

a. NEF includes a methodology that accounts for the number of occurrences by logarithmic summation of the noise intensity of all events measured in terms of Effective Perceived Noise Level (EPNL) in units of EPNdB.

b. Ldn, Leq and CNEL are based on methodologies that utilize logarithmic summation of the noise intensity of all events measured in terms of A-weighted sound pressure level in units of dBA.

c. TA is based on a methodology that measures noise intensity and accounts, by a linear summation, for the total time above a selected A-weighted sound level.

USE OF DIFFERENT INM OUTPUTS

Different INM outputs will be relevant for use for specific situations. Several examples will illustrate this principle:

1. Peak levels, reflected in the time above (TA) metric, will provide the actual noise levels at specific locations. This information will be useful for many purposes including levels of soundproofing attenuation necessary to achieve a desired interior level of noise. For instance, a concert hall will be designed according to maximum exterior noise levels in relation to the need for a quiet interior. Peak noise levels will be pertinent to the evaluation of attenuation methods. As another example, with a 15-20 dB acoustic reduction from housing structures, an indoor awakening threshold 70-75 dBA is not likely to be exceeded for those areas where outdoor noise levels do not reach 85 dBA. With the same 15-20 dB acoustic benefit from housing structure, indoor speech interference levels (approximately 65 dBA) at a separation of 8 feet should not generally be exceeded for areas where the outdoor noise level does not reach 85 dBA.

2. The time of day will be relevant to other determinations. For instance, schools are generally not sensitive to night operations. The nighttime weighting for the cumulative metrics may be misleading as applied to school locations.

3. Cumulative metrics, such as NEF or Ldn, are valuable for showing the relative impact of alternative actions. This assists the analyst in evaluating alternative courses of action.

CORRELATION BETWEEN METRICS

There are correlations among the various cumulative noise metrics. NEF is equivalent to CNEL or Ldn minus 35, plus or minus 3. For example, Ldn 65 and CNEL 65 are approximately equal to NEF 30. Basically, Ldn, CNEL and Leq are similar, within numerical constants, and differ either in the manner evening noise is weighted or in the time-of-day corrections.